SAND2015-4543PE

Used Fuel Disposition Campaign

International Collaboration: SKB EBS Task Force

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UFD Working Group Meeting
Las Vegas, Nevada – June 9 – 11, 2015

SAND 2015-????

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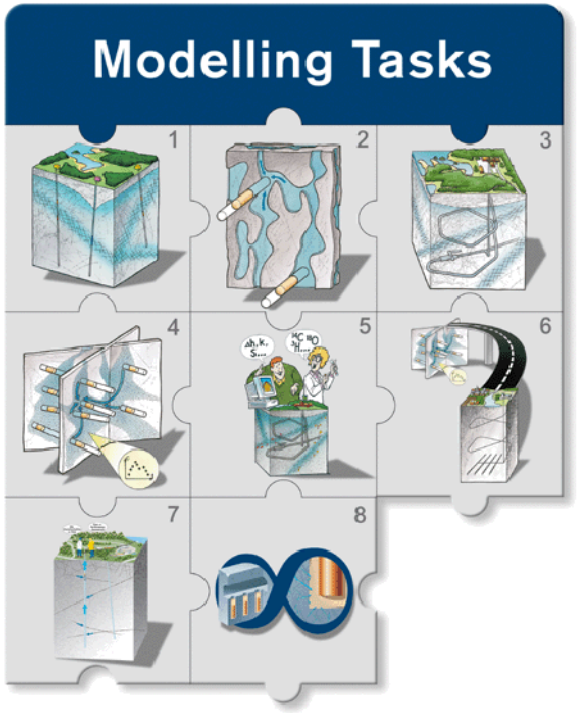
Used Fuel Disposition

SKB-Task Force

Engineered Barrier System (EBS); Modeling of Groundwater Flow and Transport of Solutes (GWFTS)

Scope: *The Task Force selects specific experiments made or to be performed by the Äspö Hard Rock Laboratory (HRL) for parallel modeling by more than one team participating in the Task Force (TF). Selection of experiments must be performed in consultation with the Äspö HRL.*

Task 1 - The LPT2 experiments, evaluation modeling
Task 2 - Äspö field tracer experiments, design modeling
Task 3 - The Äspö tunnel experiment, predictive/evaluation modeling
Task 4 - Tracer Retention and Understanding Experiments - TRUE-1, predictive modeling
Task 5 - Integration of hydrogeology and hydrochemistry
Task 6 - Performance Assessment (PA) Modeling Using Site Characterization Data (PASC)
Task 7 - Reduction of Performance Assessment uncertainty through site scale modeling of long-term pumping in KR24 at Olkiluoto, Finland
Task 8 - Interface Engineered and Natural Barriers
Task 9 - Develop models that in a more realistic way represent solute transport and retardation in the natural rock matrix.



Source: SKB TF Documentation

- Tasks 1 through 7 → Completed
- Task 8(a,b,c,d,e) → Task 8 still ongoing!!!
- Task 9 → Currently Proposed

SKB-Task Force
Engineered Barrier System (EBS)

- OBJECTIVE: "Development of general and effective tools for the advanced coupled THMC analysis of buffer and backfill behavior"
- THM:
  - Verify the capability to model THM processes in unsaturated as well as saturated bentonite buffer and backfill materials
  - Validate and further develop material models and computer codes by numerical THM modeling of laboratory and field tests and compare modeling results with measured results
  - Evaluate the influence of parameter variations, parameter uncertainties and model imperfections

- TF Aim: To support the long term work for making it possible to predict the normal THM evolution of the buffer and backfill in the repository and their interaction with the rock and the canister as well as with other system components. In addition to the normal THM evolution the possible abnormal scenarios that may occur shall also be considered.

Source: SKB TF Documentation

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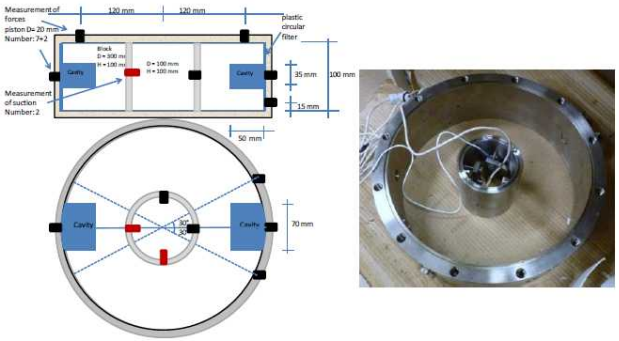
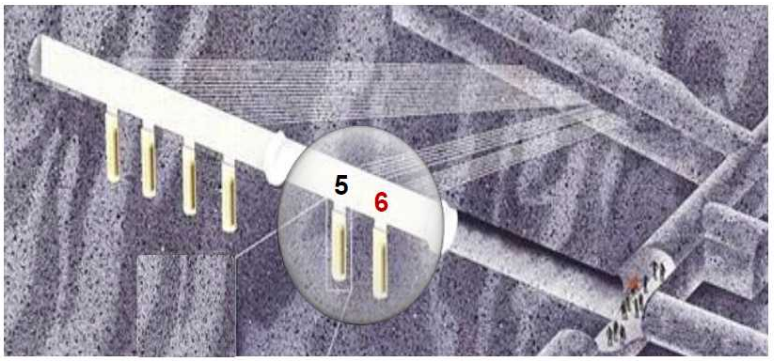
SKB-Task Force

Engineered Barrier System (EBS)

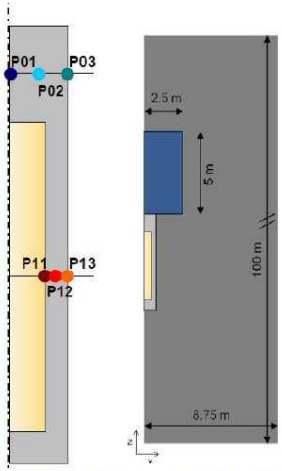
- Current THM Tasks



Homogenisation



Prototype



Sensitivity analysis

Task 8 (BRIE)
Interaction natural/engineered barrier

Source: SKB TF Documentation

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SKB-Task Force
Engineered Barrier System (EBS)
BRIE Experiment

Bentonite Rock Interaction Experiment (BRIE) Characterization of rock and installation, hydration and dismantling of bentonite parcels

Goals:

- **An increased scientific understanding of the exchange of water across the bentonite-rock interface**
- **Better predictions of the wetting of the bentonite buffer**
- **Better characterization methods of the deposition holes**

Bentonite Parcels

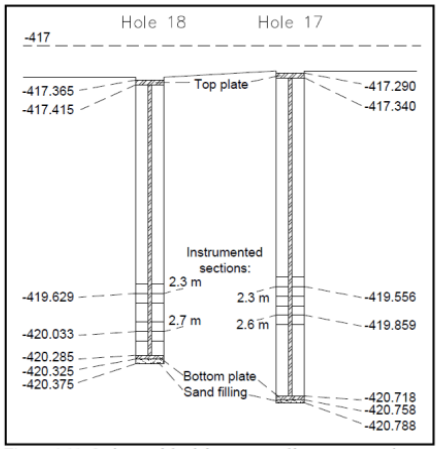


Figure 6-11. Outline and final dimensions of bentonite parcels.

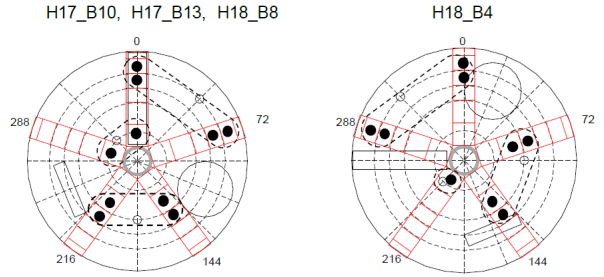


Figure 7-15. Positions for samples (filled circles) close to RH sensors (open small circles) for which water contents were related to final RH readings

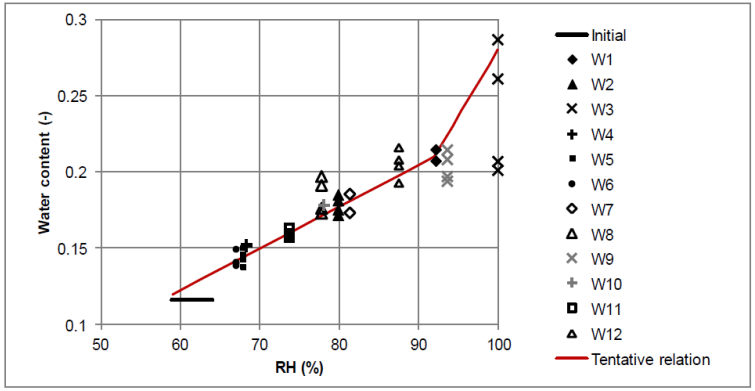


Figure 7-26. Adoption of a tentative retention relation used for translation of water content data into RH data.

Source: SKB TF Data Delivery Report
R-14-11 DRAFT 141111

Clay Hydration Modeling and Micro-Porosity Evolution

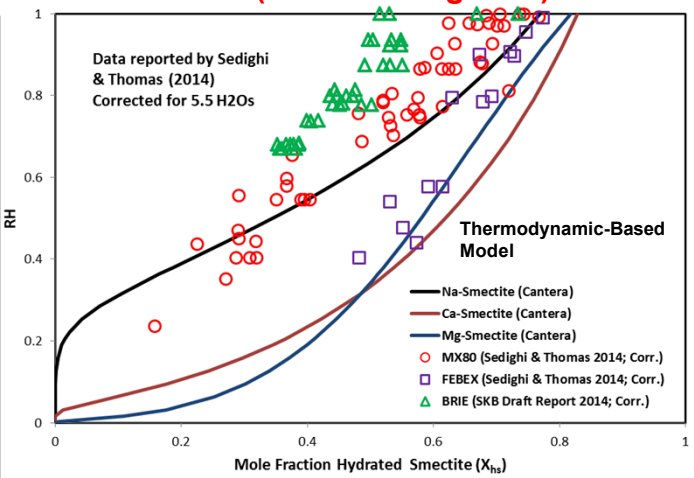
- **Relationships between swelling clay micro-porosity and clay hydration (Sedighi and Thomas 2014)**
- **Connections with clay water content and relative humidity (RH)**
- **Data retrieval from URL and laboratory experiments**
  - **FEBEX**
  - **Bentonite H2O retention**
  - **SKB TF BRIE**

Sedighi and Thomas (2014)

$$n_{micro} = X_{hs} \frac{n_c \upsilon_{il}}{Fw_{sm}} \rho_{dry}^{sm}$$

n_{micro} = Clay micro-porosity = θ_{wc}^{il} = water content
X_{hs} = Mole fraction of hydrated smectit
Fw_{sm} = Formula weight of anhydrous smectite
n_c = Number of H2Os in the interlayer
υ_{il} = Molar volume of H2O (interlayer)
ρ_{dry}^{sm} = Clay dry density

(Work in Progress!)



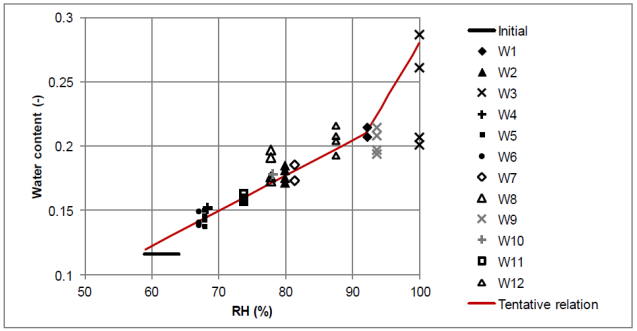


Figure 7-26. Adoption of a tentative retention relation used for translation of water content data into RH data.

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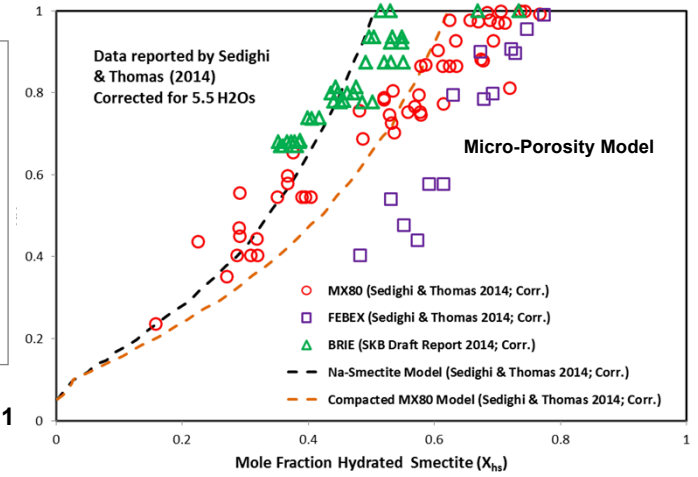
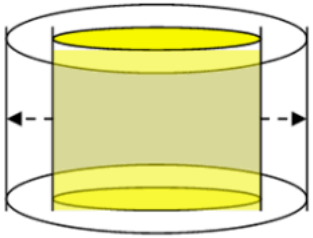


SKB-Task Force
Engineered Barrier System (EBS)

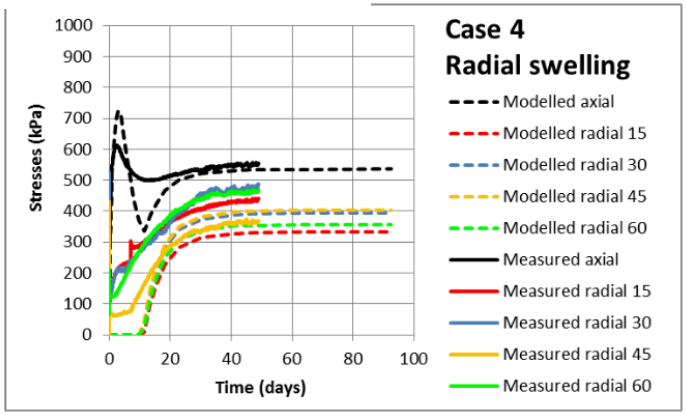
THM – Homogenization

- *Gaps, holes or inhomogeneous density distributions may prevail in the buffer or backfill material*
- *How well can the bentonite self-seal and homogenize these anomalies?*
- *Development, calibration and verification of material models and modeling techniques!*

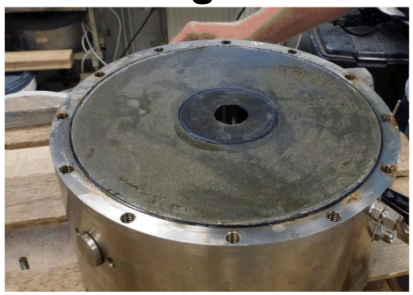
Small scale swelling test: radial swelling

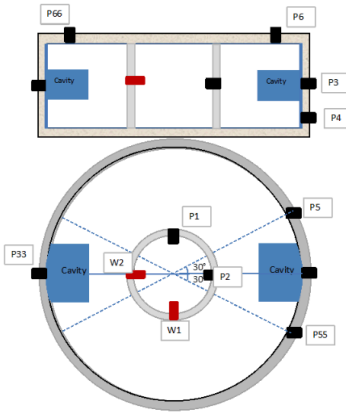


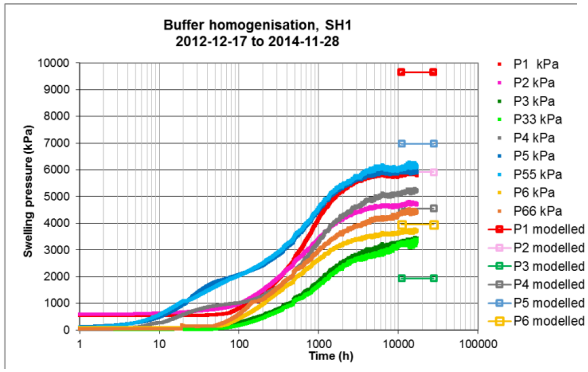
Models from Clay Technology



Large scale homogenization test





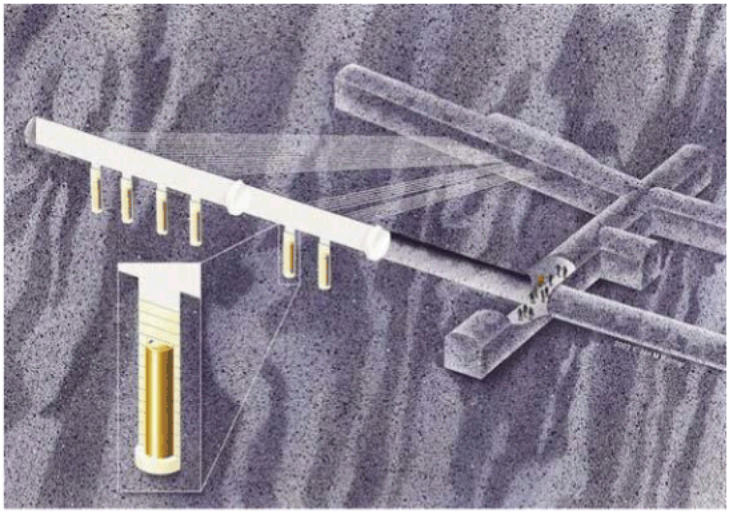


Source: SKB TF Documentation

SKB-Task Force
Engineered Barrier System (EBS)

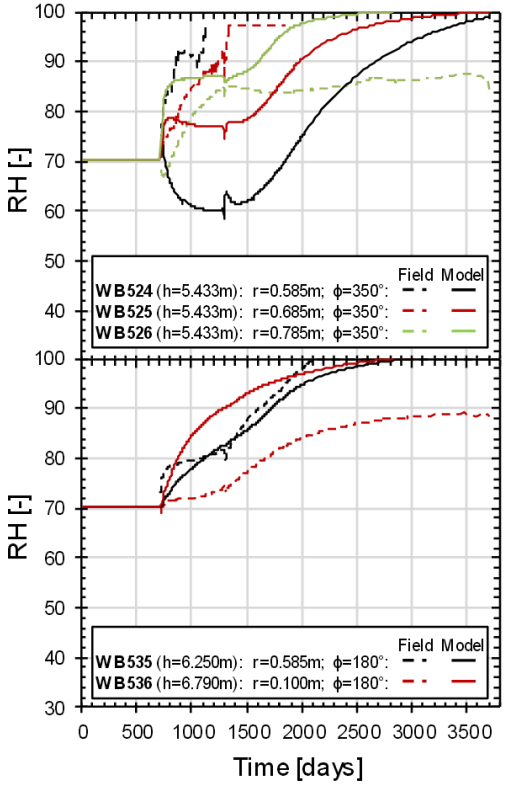
- THM – Prototype
  - *The goal is to predict the final state of the buffer in the deposition holes in the outer (now excavated) section (DH5 & DH6)*

The prototype repository: Äspö, 450 m deep



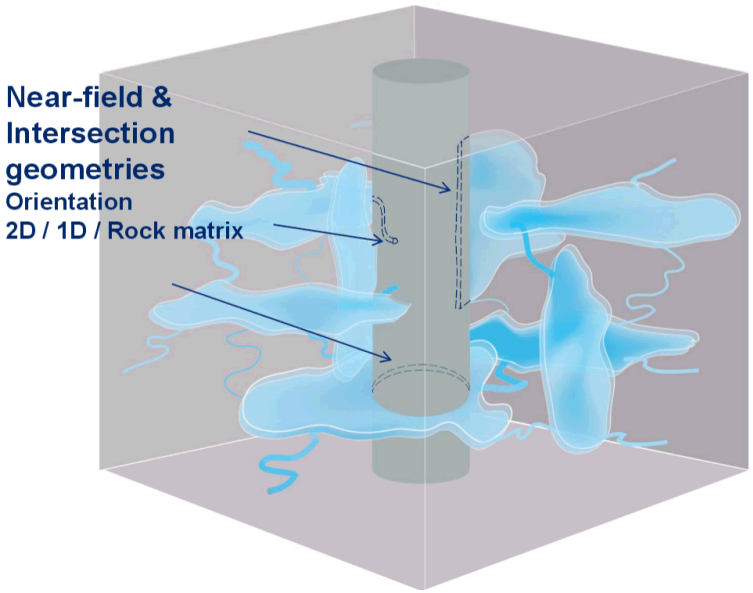
Source: SKB TF Documentation

TH model with Code_Bright



SKB-Task Force
Engineered Barrier System (EBS)

- THM – Task 8 in *GWFTS*
  - *The Bentonite Rock Interaction Experiment (BRIE) at Äspö HRL*



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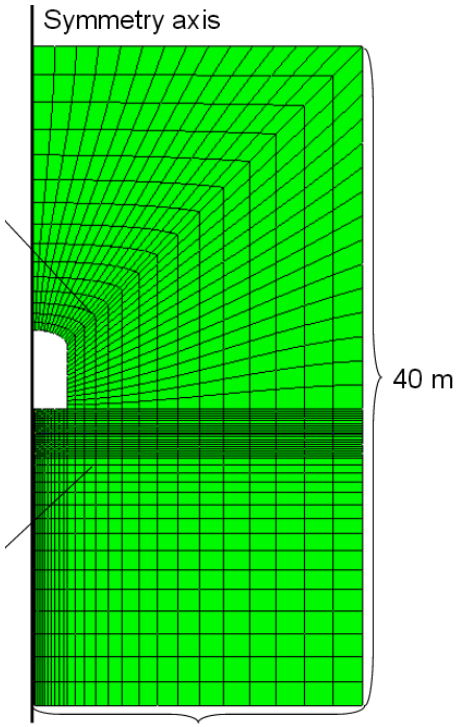
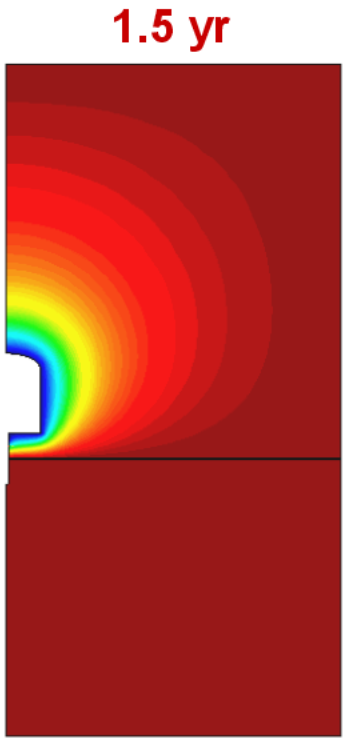




SKB-Task Force
Engineered Barrier System (EBS)

- THC - *The main focus of the "C" section was:*

  - *"To develop and test alternate porosity concepts that explain fundamental properties like ion and water transport and swelling pressure"*
  - *"To assemble experimental data sets (literature and/or own experiments) that allow testing of alternate concepts and assess so their relative merits"*
  - *"To gain insight at the molecular scale of physico-chemical processes within smectite interlayers (e.g., via MD simulations)"*
  - *"To further develop numerical tools that allow for a general implementation of these chemical aspects into a THM framework"*

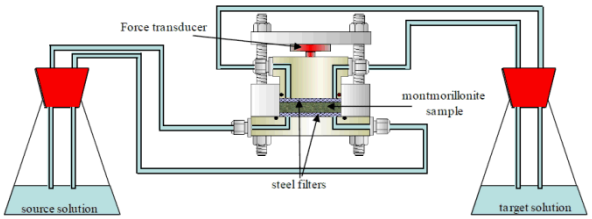
Source: SKB TF Communication
"Chemistry issues"
Dr. Urs Mäder, University of Bern

SKB-Task Force
Engineered Barrier System (EBS)

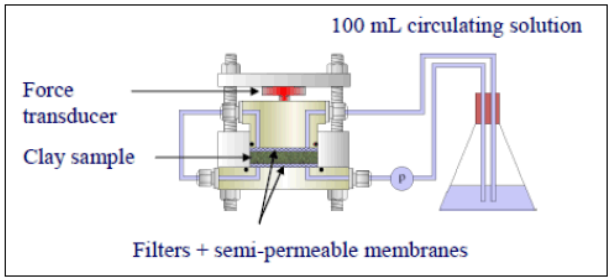
- THC – benchmarks for modeling

Five experimental benchmark data sets:

Benchmark 1: Salt diffusion in montmorillonite

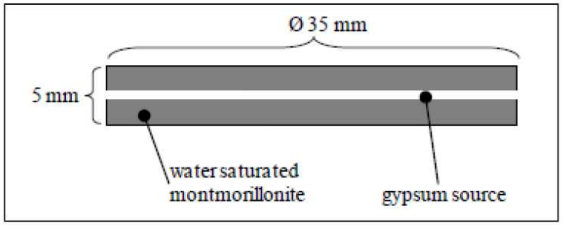


Benchmark 3: Ca/Na ion exchange in montmorillonite



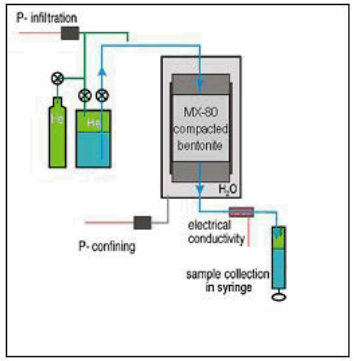
- **SKB TF Benchmark data and documentation available through web-based access**
- **Code/model development?**
- **Porosity concepts**
- **Clay-solution interactions**
- **Effects on swelling**

Benchmark 2: Gypsum dissolution in Na-and Ca-montmorillonite

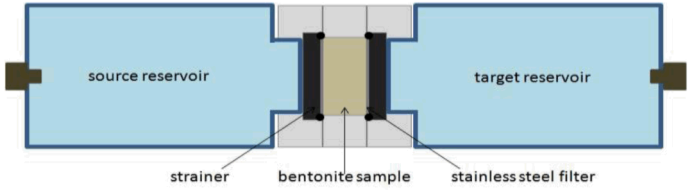


Source: SKB TF Communication "Chemistry issues" Dr. Urs Mäder, University of Bern

Benchmark 4: Multi-Component (adv-diff) transport experiment in MX-80 comp. bentonite



Benchmark 5: Diffusion of anions (Cl, Se, I) through compacted bentonite



Used Fuel Disposition

SKB-Task Force

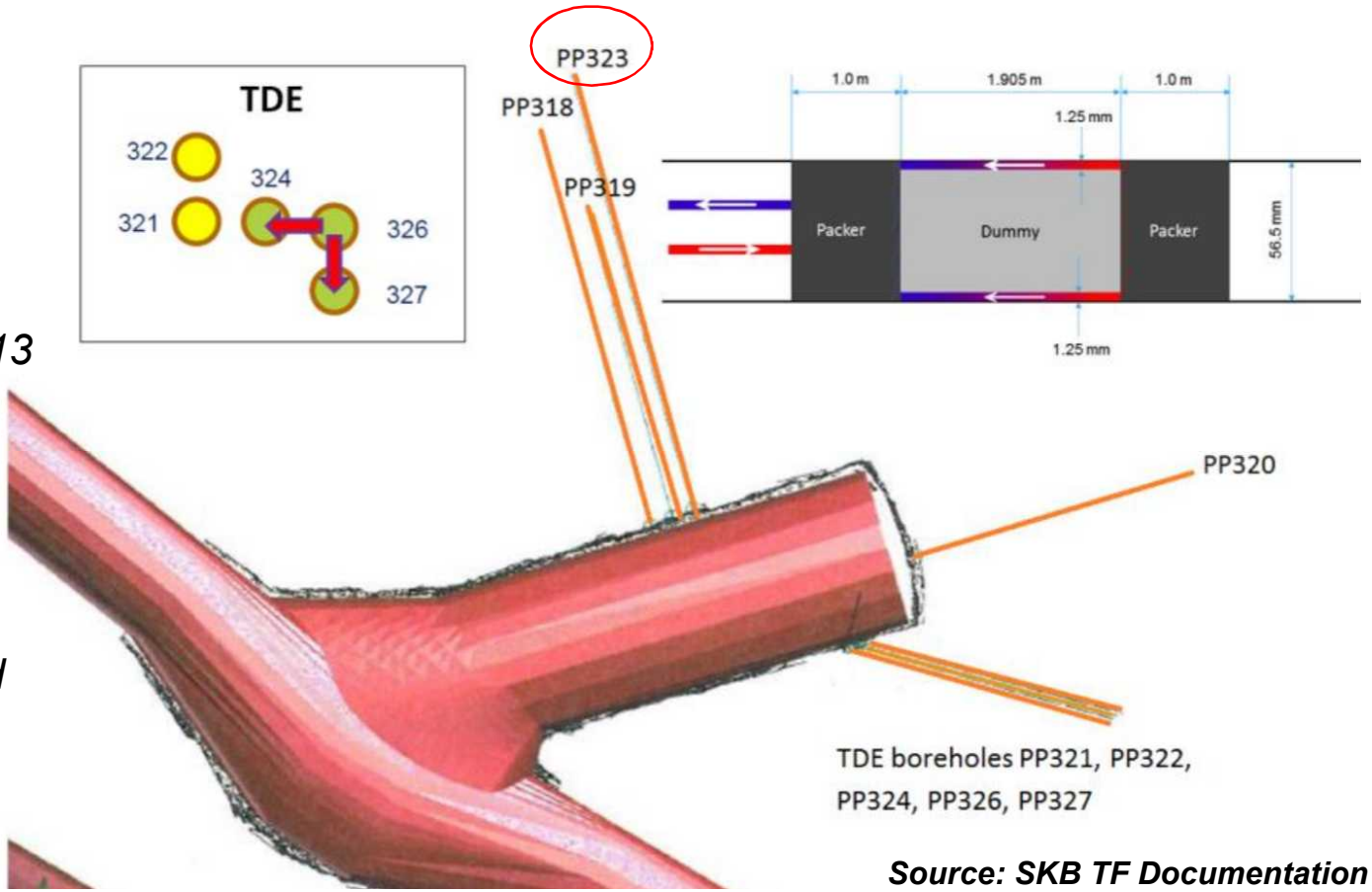
Modeling of Groundwater Flow and Transport of Solutes (GWFTS)

Task 9A – Water Phase Diffusion Experiment (WPDE)

WPDE-1: HTO, Na-22, Cl-36, I-125, tracer injection on March 2012

WPDE-2: HTO, Na-22, Cl-36, Sr-125, Ba-133 injection on January 2013

Predictive modeling results will be presented on October 2015 in Kalmar, Sweden



Source: SKB TF Documentation

SKB-Task Force
Engineered Barrier System (EBS)

- THC – Future direction
  - *Experiments discriminating among concepts (e.g., diffusive transport)*
  - *Interlayer chemistry*
  - *HM-C coupling*
  - *Soluble accessory phases that influence bentonite pore water composition*
  - *Additional issues?*
- THC – DOE-LBL participation
  - *Benchmarking*
  - *HM-C coupling*
  - *Soluble accessory phases that influence bentonite pore water composition*
- THC – DOE-SNL participation
  - *Benchmarking*
  - *Interlayer chemistry*
  - *HM-C coupling*
  - *Soluble accessory phases that influence bentonite pore water composition*
  - *Additional issues: Temperature effects?*